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SOME OBSERVATIONS ON ARTEMIA GRACILIS, THE BRINE SHRIMP OF GREAT SALT LAKE.[1]

ALBERT C. JENSEN.

Very little investigation has been made of the animal life of Great Salt Lake. This is probably because in popular literature we still read that no living thing can exist in the brine of the lake, or because the few forms adapted to such life have failed to interest scientists. So far as the author knows, no attempt has been made to make a complete scientific classification of the lake fauna or to do any extensive research work on it. The brine shrimp, *Artemia gracilis*, one of the lake forms, is a small crustacean found in great abundance.

In referring to the literature on the subject, we find that Captain Bonneville wrote short descriptions of his explorations along the shores of Great Salt Lake, making mention of small animals in the water, probably the brine shrimp, as early as 1831–1833. Fremont also states of rowing to an island in the lake where he found what he called larvæ of insects washed upon the shore in great heaps or windrows three or four feet wide, and many animals living in the water. Verrill described the brine shrimp as *Artemia gracilis* in 1869. Seven years later Dr. Siebold, of Munich, obtained through Dr. Hagen, of Cambridge, Mass., a quantity of dried mud from Great Salt Lake which contained fertile eggs of *Artemia*. These eggs were hatched in artificially prepared brine and shrimps reared therefrom. Siebold succeeded in propagating *Artemia* for several generations and was quite convinced that this crustacean reproduces parthenogenetically as well as sexually. Packard ascribes the abundance of this phyllopod in Great Salt Lake to the absence of enemies. Further, after an examination of specimens he concluded that Verrill's later described species are merely different stages of the same species and should be included under the first described form, *Artemia gracilis*. As late as 1889 David Starr Jordan stated

[1] Contribution from the Zoölogical Laboratory of the University of Utah.

that the lake water was so salty that no life could exist in it except the brine shrimp. Gilbert suggests that the presence of *Artemia* is no mystery for its ancestors may have lived in the fresh water of the basin and have transformed with the increasing saltiness of the lake. Talmage observed that the little phyllopod existed in great numbers in the lake, especially between the months of May and October. He states having collected them in the midst of winter when the temperature was far below the freezing point of fresh water, and from the evaporating ponds of the salt works, where the brine was near the point of saturation. He was able to keep them alive for several days in various dilutions of lakewater, and noted that they would even live for some time in distilled water. He further observed that repeated washings in fresh water for five minutes removed the brine so completely that salt had to be added to make them a palatable food.

The adult *Artemia*, Plate I., has a small head carrying a single black median eye (ocellus), a pair of large stalked compound eyes, two pairs of antennæ, one pair of mandibles and a pair of maxillæ. The second pair of antennæ of the female are short and pointed, while those of the male are large and broad, Plate II. The thorax bears eleven pairs of legs which are leaf-like in structure and serve as swimming organs and for the attachment of the respiratory organs. The abdomen is long, composed of eight segments without appendages. A number of bristles are to be found on the terminal segment. The ovisac is roughly bottle-shaped, being rather short and broad and attached to the first and second abdominal segments.

The œsophagus is short and leads to the stomach, which is situated in the head. The stomach is divided into two lobes, each of which receives a duct from the liver. The liver is two-lobed and lies in the head anterior to the stomach. The intestine is a straight tube. The division extending through the thorax is twice as large as that passing through the abdomen. The intestine includes a well-marked rectum, which is provided with constricting circular muscles. The ovaries are located in the first and second abdominal segments ventral to the intestine. The testes are located in the same relative position. The heart

is a long tube beginning just posterior to the mandibles and terminating in the anterior part of the last abdominal segment. It has a distinct valve at the posterior end and apparently a pair of valves for each segment, Fig. 1. The blood enters the heart through these side ostea and is forced out through the ends of the heart. The central nervous system consists of a two-lobed supraœsophageal ganglion in front of the œsophagus, and just behind the œsophagus, between the digestive canal and the floor of the body, is the subœsophageal ganglion, the first of a chain that extends through the body along the ventral side. Nerve fibers extend from these ganglia to the body and appendages.

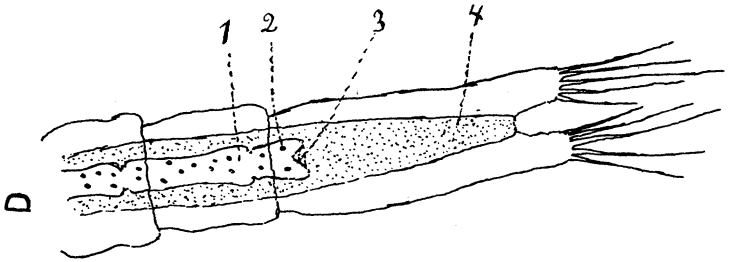


FIG. 1. Last three abdominal segments. 1, Heart; 2, blood corpuscles; 3, terminal valve; 4, intestine.

The sexes are separate in *Artemia*. The female is 10 to 12 mm. long, while the male has a length of 8 to 10 mm. Reproduction is accomplished by means of eggs that may or may not be fertilized.

In copulating the male claspers are placed around the body of the female just in front of the ovisac and thus attached the pair may swim about for several days, as many as five having been observed. At intervals the male's abdomen may be seen to bend so that the genital appendages come into contact with the oviduct. Frequently copulation takes place before the ovisac begins to show a brown color, due to the color of the eggs, and in such cases the eggs are retained in the ovisac for as long as three days after copulation has ceased. In other instances copulation does not take place until the eggs are brown in the ovisac and often these are deposited and even hatched while copulation is still in progress. It is presumed that such a copulation is too

late to fertilize the eggs for they have passed from the ovaries into the ovisac and are covered with a brown shell and are ready to be deposited. These eggs, deposited during April and May, hatch within twenty-four hours after being laid.

A comparison of these newly deposited eggs with those collected during the early spring showed no particular difference, except that none of the new eggs were cup-shaped as are many of the winter eggs, Plate III., *A*. Examination of a number of females showed the number of eggs to vary between sixteen and one hundred and twenty. The females deposit their eggs while swimming.

Eggs were collected March 8 and kept in the laboratory in normal lake water for twenty-one days. The room temperature apparently had little effect upon the development since nauplii were collected in the lake three days after individuals were observed in the aquarium.

The embryo transforms into a nauplius much unlike the adult, Fig. *E*, Plate III. It has a blood-red color, a median eye (ocellus) and three pairs of appendages, the first of which develop into the first pair of antennæ, the second pair are much larger and serve as swimming organs, while the third pair become the mandibles. After a few days the second pair, in females, become shorter, less movable, lose their bristled margins, and are transformed into small scarcely movable processes, the second antennæ, Plate II., *B*. In the males they also form the second antennæ which develop into disproportionately large claspers with broad lobes, Plate II., *A*, and are used as catching and clasping organs. Along with the early development of these are signs of segmentation which is followed by the appearance of the thoracic appendages one pair after another until all eleven pairs have been laid down. The stalked compound eyes appear about the same time as the first thoracic appendages. Within eighteen to twenty-one days the animals reach sexual maturity, shown by copulation. Sexual differences become apparent when the animals are a little more than half grown. The males are stronger and more active than the females.

Siebold's conclusion that *Artemia* may reproduce parthenogenetically is verified by my observations. Water was taken

from the lake before nauplii appeared there, and precautions taken to eliminate all eggs. Undeveloped females were placed in this water, where they developed normally and deposited eggs similar in appearance to fertilized ones. These eggs produced males and females, which developed normally and as far as could be observed could not be distinguished from those coming from fertilized eggs. A large proportion of the hatch was females. Both methods are evidently used during the summer months.

According to my records all of the brine shrimps die during the winter months, probably due to the lowered temperature. These observations do not harmonize with those of Talmage, who says: "I have taken them in the midst of winter, when the temperature of the water was far below the freezing point."

Statements made by Gilbert that the ancestors of *Artemia* may have lived in the fresh water of the basin, led to an experiment to determine the effect of different concentrations of salt water upon this animal. By using distilled water and the process of evaporation, solutions were prepared having a specific gravity as follows:

I.	II.	III.	IV.	V.	VI.	VII.	VIII	IX.
Dis. water					Normal lake water	Evapo-rated to	Evapo-rated to	Evap. to saturated point
1.000	1.027	1.044	1.064	1.085	1.109	1.130	1.711	1.179[1]

On March 28 eggs were put into the above solutions. March 30, 44 hours later, nauplii had emerged and were swimming about in solutions 1, 2 and 3 and in 4 they were emerging from the eggs. In the latter I observed the ocellus, also one or two pairs of appendages that were moving as if trying to free the body from the shell. By April 10 nauplii were emerging in solution 5 and not until April 13 did the eggs in solution 6 begin to hatch. By this date nauplii were also emerging from eggs in the lake. On May 5 a few nauplii appeared in solution 7, but in solutions 8 and 9 no nauplii had emerged. To test if the eggs in these last two solutions were fertile, a few were put into a less dense solution where they hatched readily. In solution 1

[1] The specific gravities herein given are the uncorrected hydrometer readings.

eggs hatched readily in twenty-four hours, but the nauplii lived only from one to three days. However transferring nauplii from 1 to solutions 2 to 6 inclusive brought good results. In solutions 2 to 6 the nauplii, hatched in the order stated above, lived and developed rapidly to maturity. Young and adult *Artemia* transferred to solutions 8 and 9 from less dense solutions died within five to ten hours, the young dying first. Those put into solution 7 developed slowly, while those placed into solutions 2 to 6 developed quite normally. Solutions 3, 4 and 5 however seemed to be the most favorable for the growth of *Artemia*. They would also develop normally when transferred among any of the solutions 2 to 6 inclusive.

Artemia is often found in great numbers. Fremont in writing of his explorations of the lake speaks of windrows of the brine shrimp and the pupa cases of insects washed upon shore. Talmage states having seen the surface of the water tinted by them and also of having gathered with a tow-net a quart within a few minutes. Indians inhabiting this region used to collect large quantities of the crustacean along with insect larvæ which they dried and used as food.

The brine shrimp is a vegetable feeder. Near shore may be seen many masses of an alga, *Aphanothece*, and it is along with this that *Artemia* is most abundant. This alga and its gelatinous secretion forms the principal food for the phyllopods as shown by the fact that they may be seen feeding upon it, and it can also be demonstrated in their digestive tracts. In fact this alga seems to be their only food.

Artemia gracilis is chiefly a littoral form, since in this zone its food is most abundant. However these crustaceans have been observed by Talmage in great swarms far out in the lake where they were carried by winds unless they have swarming or migratory habits.

There is a very disagreeable odor encountered upon approaching the shores of Great Salt Lake at certain places. This stench has been attributed to the decomposition of the brine shrimp. The odor is at times very offensive, which, by some, is thought to be dangerous, and as a result the summer resorts of the lake are not visited by many people who would otherwise enjoy them.

The stench is due primarily to decaying vegetable matter. Vessels placed in the laboratory containing plant material from the lake gave off the characteristic lake odor. Further the odor was present at the lake as early as the last of March, before the appearance of *Artemia*. Again the proportion of the phyllopods to the plant material is so small as to make the brine shrimp an insignificant factor in the odor production.

CONCLUSIONS.

Winter eggs of *Artemia* kept in normal lake water at room temperature (about 20 degrees centigrade) for a period of two months did not hatch earlier than those in the lake.

The embryo of *Artemia* develops into a free-swimming nauplius, much unlike the adult, which passes through a series of stages before reaching maturity.

Artemia reproduces by means of fertilized eggs and also parthenogenetically.

Eggs will hatch during the winter as well as spring and summer in dilute lake water or in fresh water at a temperature as low as 20 degrees centigrade. My experiments show also that eggs will not hatch in solutions concentrated to near the saturation point.

Artemia passes the winter months in the egg stage.

Artemia will not live in fresh water, but will in a dilution of the lake water having a specific gravity of 1.027.

Lake water diluted to a specific gravity of 1.044 to 1.027 is most favorable for the development of *Artemia*.

I take this opportunity to heartily thank Dr. Newton Miller for his assistance in this work.

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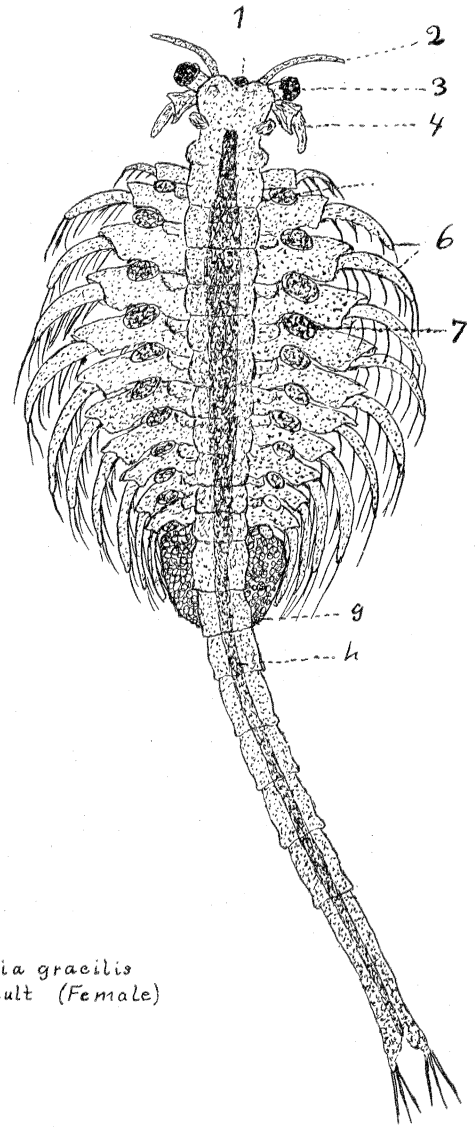
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EXPLANATION OF PLATES.

All figures drawn with the camera lucida.

PLATE I.

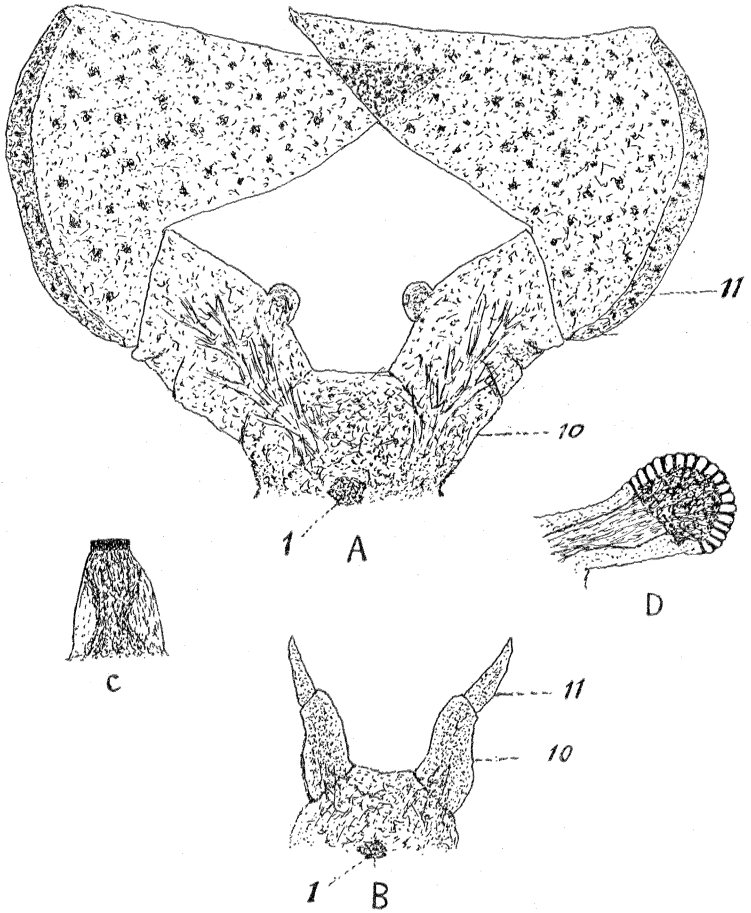
Adult female *Artemia gracilis*.



Artemia gracilis
Adult (Female)

PLATE II.

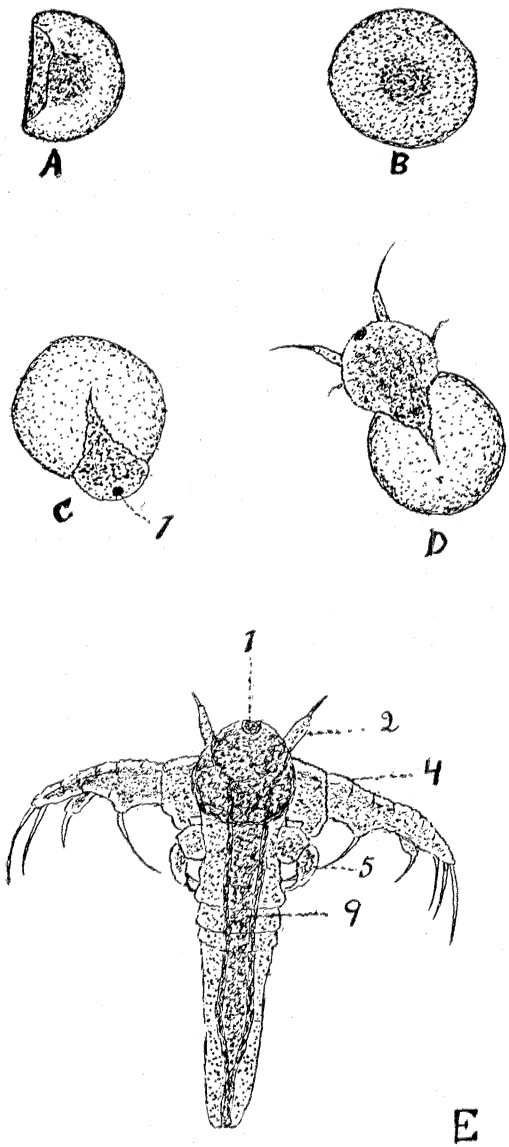
A. Head of male showing first pair of antennæ.
B. Head of female showing first pair of antennæ.
C. Mandible.
D. Compound eye.
Figures of this plate drawn on the same scale.



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PLATE III.

A. Cup-shaped egg.
B. A spherical egg.
C and *D*. Nauplii emerging from eggs.
E. Early nauplius stage.

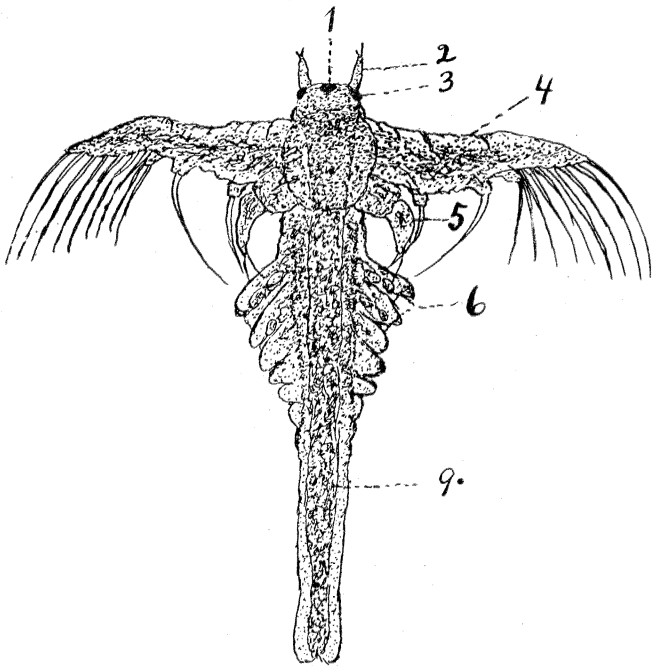


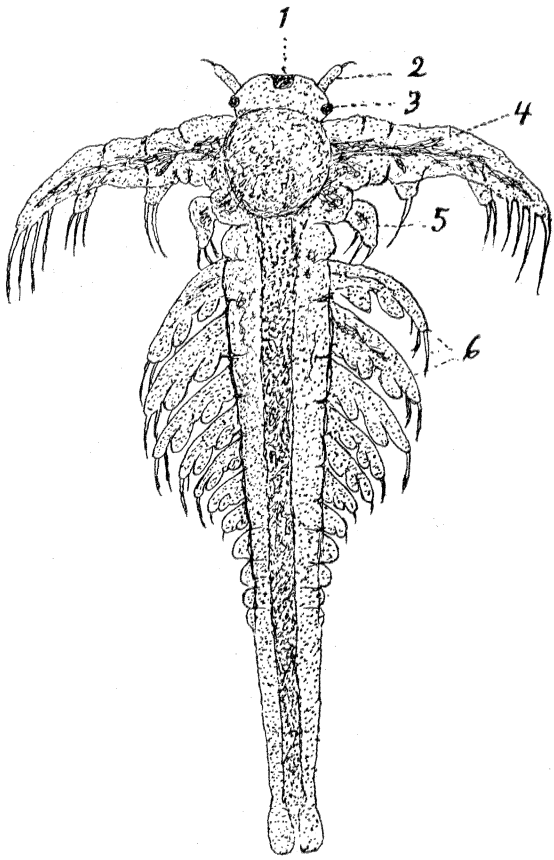
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PLATE IV.

Later nauplius stages.
Figures of plates III. and IV. drawn on the same scale.
Notations.

1. Ocellus.
2. First antenna.
3. Compound eye.
4. Second antenna.
5. Mandible.
6. Thoracic appendages.
7. Gills.
8. Ovisac.
9. Intestine.
10. Basal segment of the first antenna.
11. Distal segment of the first antenna.





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